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Functions and Requirements for a Waste Conveyance Jet Pump for the Gunite and Associated Tanks at Oak Ridge National Laboratory

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1.0 INTRODUCTION

1.1 BACKGROUND

Since the mid 1940's, the U.S. Department of Defense (DOD) and the U.S. Department of Energy (DOE) have conducted research and development activities at the Oak Ridge National Laboratory (ORNL) in support of urgent national interests in the fields of nuclear weaponry and nuclear energy. Some of these activities resulted in radiologically hazardous waste being temporarily deposited at ORNL in Waste Area Grouping 1. At this location, waste is stored in several underground storage tanks, awaiting ultimate final disposal. There are tanks of two basic categories; one category is referred to as the "gunite" tanks, and the other category is "associated" tanks.

The ORNL Gunite and Associated Tanks Treatability Study (GAAT-TS) project was initiated in fiscal year (FY) 1994 to support a record of decision in selecting from seven different options of technologies for retrieval and remediation of these tanks. This decision process is part of a Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), Remedial Investigation and Feasibility Study (RI/FS) presented to DOE and the Tennessee Department of Environment and Conservation (TDEC). As part of this decision process, new waste retrieval technologies were evaluated at the 25-ft diameter gunite tanks in the North Tank Farm.

A system comprised of a dislodging end effector employing jets of high-pressure water, coupled to a conveyance system motivated by a commercial jet pump has been demonstrated by GAAT-TS as a viable retrieval technology for the GAAT waste retrieval tasks. This system is to be moved to the South Tank Farm and used for retrieval of wastes there.

The commercial jet pump used in the GAAT-TS was effective, but some improvements were deemed warranted:

- The commercial pump eductor was prone to rapid erosion of the mixing nozzle and premature failure. The commercial pump's jets do not converge at a central point in the eductor, which may contribute to the erosion of the eductor nozzle.

- The motive jet nozzles are difficult to replace, requiring disassembly of the contaminated pump, and require frequent replacement because the hex tool sockets are rapidly corroded/eroded to the point where they are useless, requiring that the nozzles be drilled out of the expensive pump body, a risky process.

- The dilution ratio (waste/(waste + water)) achieved for the test campaigns was not as good as was hoped for. This may be due, in part, to inefficiency of the commercial jet pump in some of the prevalent operating modes, where a significant fraction of air is admitted at the confined sluicing end effector 's (CSEE) suction inlet port.

The objective of developing the improved jet pump is to alleviate the shortcomings of the commercial pump.

1.2 SCOPE

This document addresses redesign of a jet pump, which can serve many applications. For this particular application the improved jet pump will be used for the ORNL GAAT Waste Dislodging and Conveyance system. All systems beyond the interface at the jet pump inlet, outlet and motive water connection are part of the balance of plant. The existing motive pump and the second Hose Management Arm (HMA) being built for the South Tank Farm retrieval campaign define the interfaces for the jet pump.

1.3 ASSUMPTIONS AND UNKNOWNS

Some requirements and parameters specified in this document are not fully defined at this time, but remain to be determined (TBD) before the WD&C design can be finalized. Such incompletely defined terms are identified in the text of this document by the symbol (TBDXX), where the XX represents a 2-digit number for that particular unknown or family of unknowns. A complete listing of all TBD's is found in Section 6 of this document.

1.4 ACRONYMS AND ABBREVIATIONS

The acronyms and abbreviations used in this document are defined as follows:

ANSI — American National Standards Institute.

BOP — Balance of Plant. The BOP is a term used to refer inclusively to all other portions of the waste retrieval process not included in the WD&C system defined in this document.

CCC — Confinement Contamination Control. Enclosure on top of riser equipped for glove ports, windows, and access doors.

CERCLA — Comprehensive Environmental Response, Compensation, and Liability Act of 1980.

CSEE — Confined Sluicing End Effector.

DOD — U.S. Department of Defense.

GAAT — Gunite and Associated Tanks. Refers to the underground waste storage tanks in the North and South tank farms at ORNL.

GAAT TS — Gunite and Associated Tanks Treatability Study. A project started in FY 1994 to support a record of decision on remediation of waste at ORNL.

HMA — Hose Management Arm. The mast and extendible pipe boom used to house and deploy the in-tank elements of the Waste Conveyance System, including the Jet Pump.

ITH	In-Tank Hardware. The tank being processed may contain various items of scrap metal, tools, or other articles that have been tossed into it as radioactive "scrap". All such scrap and structures are considered to be ITH.
MAWP	Maximum allowable Working Pressure (see 3.1.3).
MOP	Maximum Operating Pressure (see 3.1.3).
MLDUA	Modified Light Duty Utility Arm. A Light Duty Utility Arm in production with special modifications to comply with ORNL applications (e.g., increased load capacity, etc.).
ORNL	Oak Ridge National Laboratory. The Federal Government facility at Oak Ridge, Tennessee, where the WD&C system will be employed.
NTF	North Tank Farm - Tanks W-1 through W-4 of the GAAT.
STF	South Tank Farm - Tanks W-5 through W-10 of the GAAT.
TBD	To Be Determined. Requirements and parameters specified in this document, which are not fully defined at this time, but remain to be determined before the WD&C design can be finalized (see Section 9).
Waste	In this document the term "waste" refers only to those chemical compounds stored in the tank, which were the result of past processing of various chemical and nuclear materials, and does not include various ITH found within the tank.
WCS	Waste Conveyance System. That portion of the WD&C system that receives waste from the WDEE and transfers it above ground to the BOP.
WD&C	Waste Dislodging and Conveyance. The overall system of equipment (excluding the MLDUA or crawler and the GEE) directly used to dislodge and convey waste from inside the GAATs underground storage tanks to the interface with the BOP.
WDEE	Waste Dislodging End Effector. That portion of the WD&C system used to dislodge waste from the tank and transfer it to the Waste Conveyance System.

2.0 FUNCTIONS

Equipment functions described in this document are based upon the results of research and development activities recently completed or in progress at the Hanford nuclear reservation at Richland, Washington, and the University of Missouri-Rolla. (Ref. 0)

2.1 WASTE CONVEYANCE SYSTEM DESCRIPTION

The primary function of the Waste Conveyance System is to receive waste from the WDEE, convey it above ground, and deliver it to the BOP interface. The WCS includes the Hose Management Arm and mast, the jet pump, and the jet pump motive water pump.

2.1.1 The Hose Management Arm

The HMA is the inlet conduit to the jet pump. The HMA is a 6-m (20-ft) articulated boom of 2 in. IPS Schedule 40 steel pipe with a 2.4-m (8-ft) or 4.6-m (15-ft) hose tail to the end effector. It is cantilevered from the bottom of the HMA mast, which is lowered into the tank through a riser. The jet pump discharge pipe is vertical upward for about 7.6 m (25 ft) to the Confinement and Contamination Control box where it connects to the balance of plant piping with a hose jumper.

2.1.2 Jet Pump

The Jet Pump mounts directly to the HMA pipe inside the HMA mast, in a vertical orientation.

2.1.3 Motive Water Pump

The motive water pump provides up to 70 Mpa (10,000 psi) at 40 L/min (10 gpm), delivered to the jet pump by 12-mm (1/2-in.) ID pipe and a hose jumper.

2.2 JET PUMP FUNCTION

2.2.1 Slurry Pumping

The jet pump must match or exceed the performance of the commercial pump (Figure 2.2) at pumping water under inlet and discharge conditions defined by the test loop at the University of Missouri (Figure 2.1).

2.2.2 Dilute-Phase Pumping

The jet pump must match or exceed the performance of the commercial pump (Figure 2.3) at pumping air with entrained water spray under inlet and discharge conditions defined by the test loop at the University of Missouri.

2.2.3 Particle Size Tolerance

Pieces of waste or ITH of sufficient size to lodge and create a flow blockage within the jet pump are likely to be encountered by the WDEE. The WDEE is equipped with an inlet screen having 9-mm (3/8-in.) hex openings. The jet pump should tolerate any object that might credibly pass through the inlet screen.

2.2.4 Erosion Resistance

The jet pump must exhibit greater erosion resistance than the commercial pump.

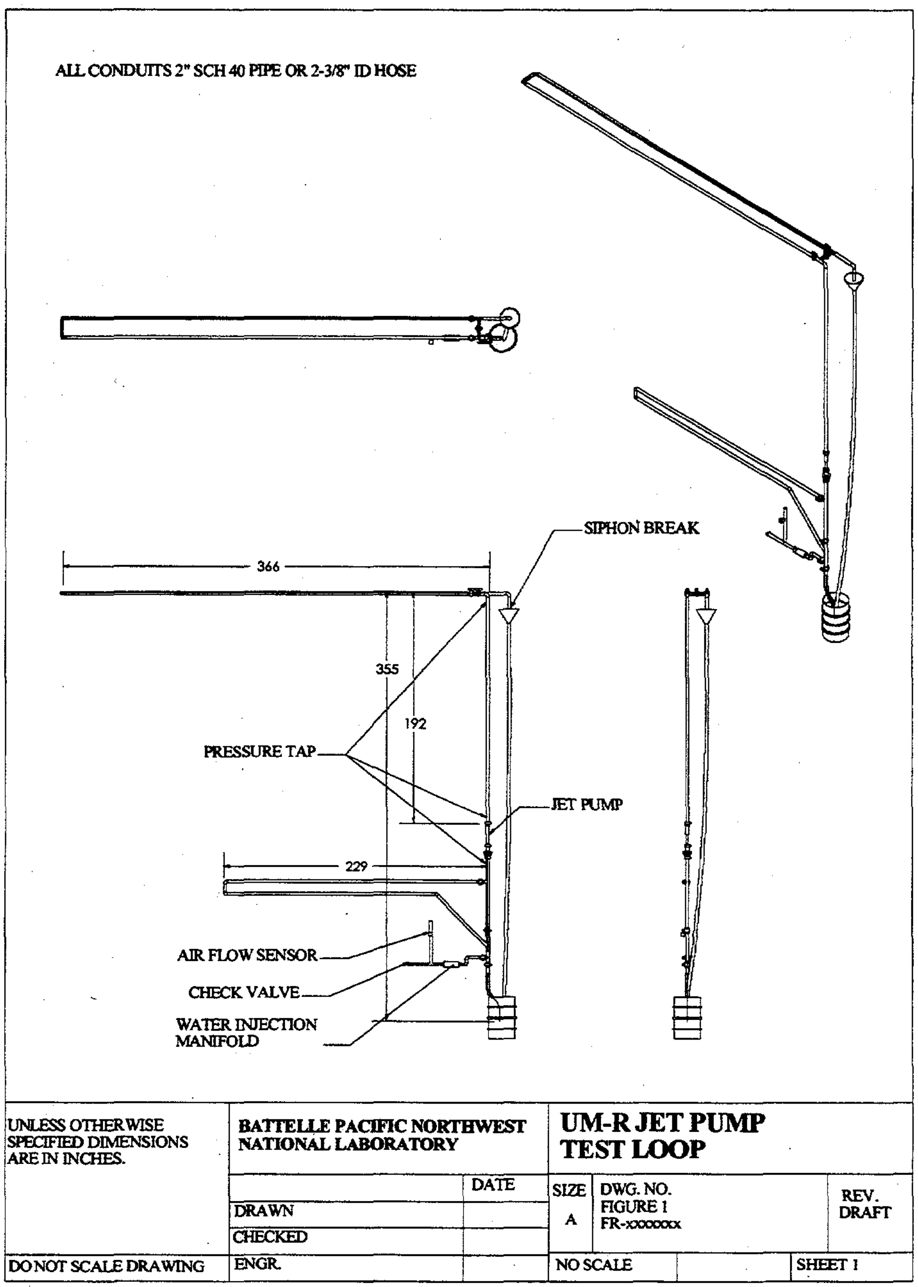

Figure 2.1. Test Loop Diagram

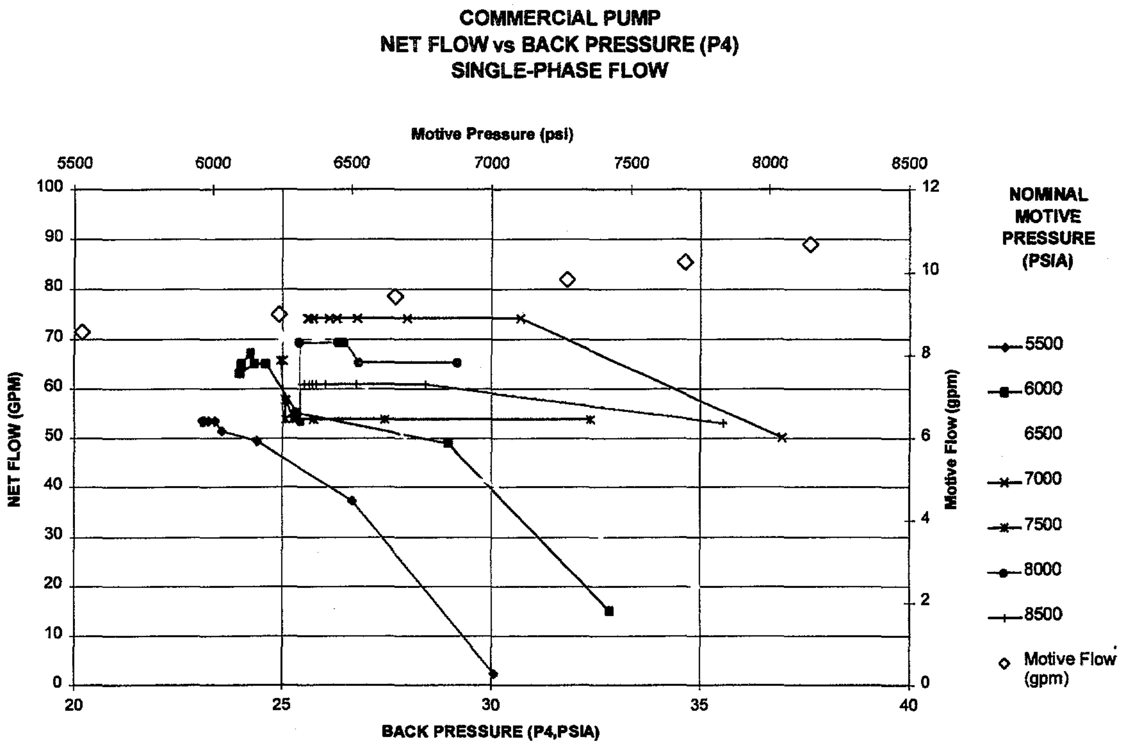

Figure 2.2 Commercial Pump Test Results (Single-Phase)

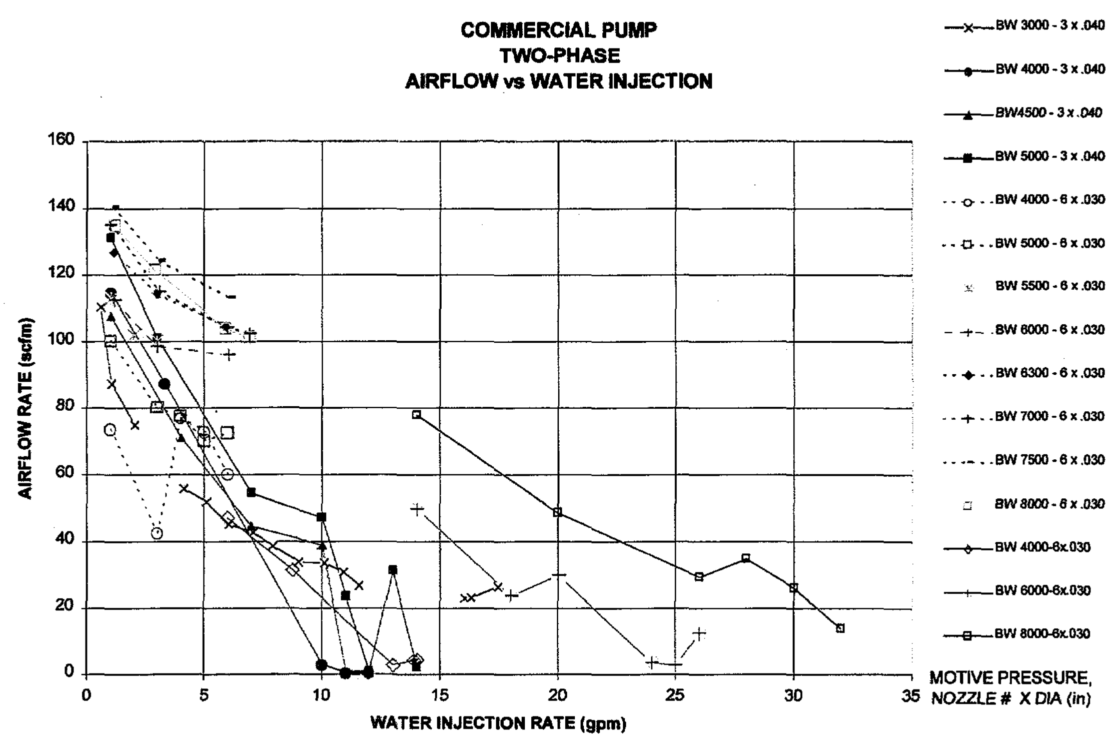

Figure 2.3. Commercial Pump Test Results (Two-Phase)

3.0 REQUIREMENTS

This section of the document defines the WD&C System requirements applicable to the design of the jet pump.

3.1 DESIGN REQUIREMENTS

3.1.1 Environment

Those portions of the WD&C equipment which are exposed to the interior of the waste tank must be designed to remain fully operational and achieve full design life (Reference 12, Section 3.1.5) when subjected to the following normal in-tank environment.

3.1.1.1 Tank Contents

Tank waste, covered by an aqueous supernate, with a vapor air space above the supernate.

3.1.1.1.1 Tank Waste Properties

Note: Tank waste sampling and characterization data is very limited. Information following is "best estimate" and should be used conservatively (see Reference 4).

1. Chemical - Non-heat generating, not sensitive to impact, rubbing or abrasion. The pH may vary from 7 to 11. Organic compounds (not identified, but including ~100 ppm concentrations of "light hydrocarbon", ~1500 ppm tri-butyl phosphate, and less than 10 ppm each of anthracene, fluoranthene and pyrene) were detected in the W-3 sludge, and may be expected in the South Tank Farm wastes, as are nitrates, phosphates and sulfates.

2. Physical - Silty, clay, pasty particles; some crystallized solids which may have formed during storage; contains lumps of gunite which may have eroded from the tank walls and miscellaneous debris such as plastic bags, coveralls, metal cans (sources: anecdotal and Reference 4). Some waste forms may be highly abrasive. Slurry density may range from 1.0 g/ml to 1.47 g/ml. Solids density may exceed 2.0 g/ml.

- Thermal - Temperature may range from 4° to 27°C (40° to 80°F)
- Radiological - 100 mR/hr to 25 R/hr, point sources of up to 50 R/hr.

3.1.1.1.2 Supernate Properties

1. Chemical - Water, containing some soluble material from the tank waste. May be a thicker transition phase close to waste surface. The pH may vary from 7 to 11. Conductivity 10 -20 μmho/cm. Organic compounds are present in concentrations of 200 - 8500μg/g. Note that tank W-10 contains PCBs >2ppm but <10ppm.

2. Physical - Density may range from 0.99 g/ml to 1.06 g/ml. Viscosity approximately equal to that of water. There may be a density gradient near the surface of the waste or the suction leg of the pump may begin to pump more dense and viscous material as the level of the supernate approaches the sludge surface.

- Quantities - Supernate depth may be from 0.06 m to 2.8 m deep.
- Thermal - Temperature may range from 4°to 27°C (40° to 80°F).
- Radiological - 100 mR/hr to 25 R/hr.

3.1.1.1.3 Vapor Space

1. Chemical - Air, containing vapors emitted from the supernate. Non-flammable, non-explosive.

2. Physical - Pressure may vary from -124 Pa to 0 Pa (-0.5 to 0 in. H_20) (gage pressure). Relative humidity ranges from 4% to 100%.

3. Thermal - Temperature may range from 4° to 27°C (40° to 80°F).

3.1.2 Codes and Standards

The WD&C system is an assemblage of temporary outdoor equipment and shall not be classified as, nor have to meet the requirements of, a permanent facility.

Piping shall be in accordance with ANSI-B31.3.

3.1.3 High-Pressure Waterjetting Systems Design Requirements

These requirements are exerpted from Reference 12 and 13.

3.1.3.1 Definitions

1. Burst Pressure - The internal pressure within a component of a high-pressure water jet system at which it will fail.
2. Dynamic Testing - A test carried out under pressure during which the unit is subjected to the internal pressure designated for the test with the test to include both the time variant loads to which the unit will be subject during operation (such as pump piston oscillation and the on and off triggering of other system units) and on and off cycling of the pressure supply.

3. Manned Operation - Equipment or components which may be pressurized while not isolated from all personnel by a physical barrier or distance as defined by the ORNL High Pressure Committee considered to be under manned operation and shall be rated accordingly.

4. Manufacturer's Designated Burst Pressure - That pressure at which either physical testing has shown that a component will fail, or at which the manufacturer has carried out physical testing of the component to validate that it will survive. The latter may be designated as burst pressure if testing to failure is not practical.

5. Maximum Allowable Working Pressure (MAWP) - The maximum pressure, recommended by the manufacturer, at which a component is to be used. The MAWP shall not exceed forty percent (40%) of the burst pressure of the component for unmanned operation or twenty five percent (25%) of the burst pressure for manned operation. A system is not to be operated above the lowest maximum

allowable working pressure of any of its components. All pressure systems shall be equipped with a safety device to limit the system pressure to the maximum allowable working pressure of the weakest component, with a tolerance of 10%.

6. Maximum Operating Pressure (MOP) - The pressure at which the system is designed to normally operate, not greater than ninety percent (90%) of Maximum Allowable Working Pressure (80% for systems subject to frequent or large pressure cycles). System controls shall have the maximum operating pressure clearly posted and accurate direct pressure indication clearly visible to an operator using system pressure controls.

7. Proof Testing - A series of tests carried out to validate that a piece of equipment or component will withstand the operational conditions under which it will be used. This shall include operation for at least one hour at a pressure 1.5 times that of the working pressure.

8. Static Testing - A test carried out in which the piece of equipment or component is *subjected to an internal pressure, without fluid flow through the unit.* For equipment subject to time varying loads such as pump pulsation, the static test shall be conducted using similar time varying loads.

3.1.3.1 Requirements

3.1.3.1.1 Operational Constraints

All high-pressure (>500 psi) equipment for waterjetting and jet pump operation shall be operated at less than the Maximum Allowable Working Pressure (MAWP). The MAWP for the new jet pump shall be 11,100 psi (77 Mpa). MOP shall be 10,000 psi (69 Mpa).

3.1.3.1.2 Rating

All high-pressure equipment for waterjetting and jet pump operation shall be rated with a MAWP, which is to be established according to the above definitions, either:

a) by the manufacturer, for parts produced in volume, carrying a part number and a published pressure rating, and produced under an accepted quality assurance program.

b) by testing of like items, manufactured from certified like materials under an accepted quality assurance program, to Burst Pressure or Manufacturer's Designated Burst Pressure. Articles so tested are not to be used. The testing for the Manufacturer's Designated Burst Pressure shall be either a dynamic or static test, as appropriate to the duty cycle in the application.

c) for one-of-a-kind, specially-fabricated or experimental parts deemed too expensive for destructive testing, by detailed analysis (to include hand calculations or finite-element analysis) of all loads (including internal pressure, external forces, shock loading, and fatigue) conceivably imposed on the item. For articles intended for manned operation, design stresses at the MAWP are to be less than allowable design stresses at the working temperature as defined by ANSI B31.1 Code for

Power Piping, 1989 Edition, Section 302.3 - Allowable Stresses and other Stress Limits and the referenced tables. For any materials not defined therein, the allowable design stress shall be not greater than 25% of the yield stress as published by the manufacturer of the material. For components intended for unmanned operation, the allowable design stress may be increased to 40% of the yield stress. All components rated under this definition shall be manufactured from certified materials and Proof Tested.

The pressure-containing body or bodies of the equipment shall be indelibly stamped or engraved with the MAWP, clearly designated as such and including units.

3.1.3.1.3 Proof Testing

An operational model of specially designed or prototypic equipment, having a Manufacturer's Designated Burst Pressure established in accordance with 3.1.3.1.2 (b) or (c), will be subjected to Proof Testing, and so certified by the manufacturer, before being used in a system. The proof testing shall be carried out using both Static and Dynamic testing of the component.

3.1.4 Tank Pressure

The jet pump shall not create a positive pressure within the tank, nor within its own confinement system, as measured relative to ambient.

3.1.5 Waste Dilution

The addition of new water to a tank/tank waste by the jet pump shall be minimized.

3.2 MAINTENANCE

3.2.1 Service Interval

The jet pump shall be designed to operate for a minimum of 80 hours without scheduled or planned maintenance. Exceptions may be made, subject to prior engineering approval.

3.2.2 Maintainability

The jet pump shall be designed for manual replacement of the wearing parts while within the confinement contamination control (CCC) system confinement, using common glovebox techniques.

Human factors shall be taken into consideration and a modular design approach shall be implemented to ensure ease of equipment setup, operation, maintenance, and removal.

3.2.3 Decontaminability

Those portions of the jet pump subject to being contaminated and requiring gross decontamination shall be designed to avoid cracks, crevices, or enclosed voids, which can entrap contamination and impair decontamination efforts.

The jet pump is subject to gross decontamination operations and shall be designed to withstand high-pressure water spray of 3.4 MPa (500 psig) maximum delivered through round jet nozzles at a rate of 6 l/m/nozzle (1.5 gpm/nozzle) from a distance not greater than 100 mm (4 in.).

3.3 MATERIALS AND PROCESSES

3.3.1 General

Materials and processes used in fabrication of the jet pump shall enable the equipment to comply with all design requirements specified in this document, including design life, operating and storage environments, and decontamination operations.

3.3.2 Standards

Materials and processes shall be in accordance with the standards cited herein.

3.4 INTERFACES

3.4.1 Waste Conveyance System

3.4.1.1 Physical Interfaces with Conveyance Piping

The jet pump shall terminate in 2 in. Schedule 40 IPS Groove-joint ends as interfaces to the BOP.

3.4.1.1.1 Size

The overall length of the jet pump shall fit between pipe ends spaced 623.8 mm (24.56 in.) apart, with suitable allowances for the flexible groove-joint standard connectors used.

3.4.2 Interface between WD&C Utilities and Jet Pump

3.4.1.2 Motive Water Supply

The jet pump shall be supplied with motive water by an existing 3/4-in. IPS XXS pipe in the HMA. Connection to the jet pump is to be made with a hose jumper terminating at the jet pump in a 1/2 FPT x 9/16 MP-F gland and collet fitting (Butech Model 10F9M8P or equal) or a 1/2 FPT x 9/16 MP-M adapter (Butech Model 10F9M8P or equal).

3.4.2.2 Connections

The method of attachment/detachment of the jet pump to its utilities and the conveyance system piping shall be accomplished with simple hand tools, using manual glovebox techniques.

4.0 SAFETY AND QUALITY ASSURANCE

4.1 SAFETY

The design of the WD&C equipment shall be governed by Reference (TBD 4).

4.2 QUALITY ASSURANCE

Quality assurance requirements are defined in References (TBD 5).

5.0 REFERENCES AND BIBLIOGRAPHY

References are carried over from the GAAT-TS Waste Retrieval System F&R pending determination of the governing documents for STF operations under the new ORNL contractor.

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2 Fuqua, J.R. February 1995. "GAAT TS; Functional Requirements Document"; Systems Engineering Division of Energy Systems Central Engineering, Martin Marietta Energy Systems, Inc.

3 M.W. Rinker, O.D. Mullen, and B.K. Hatchell. Waste Dislodging and Conveyance Testing Summary and Conclusions to Date. PNL-10095, Pacific Northwest Laboratory, Richland, Washington.

4 Martin Marietta Energy Systems, Inc. *Results of Fall 1994 Sampling of Gunite and Associated Tanks at the Oak Ridge National Laboratory*, Oak Ridge, Tennessee, ORNL/ER/Sub/87-99053/7.

5 ORNL; GAAT TS Engineering Criteria Packages 1 - 4, Rev A (Draft) ET# GAAT 066.

6 Robotics and Process Systems Division Quality Assurance Program Manual.

7 ORNL/ER-225/R1, Quality Assurance Plan for the Oak Ridge National Laboratory Environmental Restoration Program.

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9 ORNL QAP-X-92-RPS-001, Rev 0; Oak Ridge National Laboratory Robotics and Process Systems Division Telerobotic Systems Section; Quality Assurance Plan for Research and Development Projects.

10 ORNL QAP-X-92-RPS-002, Rev 0; Oak Ridge National Laboratory Robotics and Process Systems Division Telerobotic Systems Section; Software Quality Assurance Plan for Research and Development Projects.

11 ORNL RPS-2-11, Rev 3; Oak Ridge National Laboratory Robotics and Process Systems Division Quality Assurance Standard.

12 WHC-SD-WM-FRD-024, Rev. 1; Functions and Requirements for Waste Dislodging and Conveyance System for GAAT-TS at Oak Ridge National Laboratory" 1995, Westinghouse Hanford Co. (Rev 1 by ECN 617523).

13 Department of Energy "High-Pressure Systems Safety Manual" (Draft).

6.0 TBD/HOLD REPORT

TBD Number	4
Reference	Paragraph 4.1
Description of TBD	Safety requirements references
Comment/Impact of TBD	Design and fabrication of test article proceeding at risk
Responsible Organization	XL – John Emison
Due Date	April 10, 1998
Resolution	Not resolved ATP due to contractor and program transition at ORNL

TBD Number	5
Reference	Paragraph 4.2
Description of TBD	QA requirements references
Comment/Impact of TBD	Design of test article proceeding at risk
Responsible Organization	XL – John Emison
Due Date	April 10, 1998
Resolution	Not resolved ATP due to contractor and program transition at ORNL

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